# **Digital Elevation Models of Sand Point, Alaska:** Procedures, Data Sources and Analysis

Prepared for the Pacific Marine Environmental Laboratory (PMEL) by NOAA National Geophysical Data Center (NGDC) March 2012

Love M.R.<sup>1</sup>, D.Z. Friday<sup>1</sup>, P.R. Grothe<sup>1</sup>, K.S. Carignan<sup>1</sup>, B.W. Eakins<sup>1</sup>, and L.A. Taylor<sup>2</sup>

Corresponding project contact: Lisa A. Taylor NOAA, National Geophysical Data Center Marine Geology and Geophysics Division 325 Broadway, E/GC 3 Boulder, Colorado 80305

Phone: 303-497-6767 Fax: 303-497-6513

E-mail: Lisa.A.Taylor@noaa.gov http://www.ngdc.noaa.gov

<sup>&</sup>lt;sup>1</sup>Cooperative Institute for Research in Environmental Sciences, University of Colorado at Boulder

<sup>&</sup>lt;sup>2</sup>NOAA, National Geophysical Data Center, Boulder, Colorado

# **Contents**

1.	Intro	duction	1	1
2.	Stud	y Area		2
3.	Sour	ce Elev	ration Data	4
	3.1	Data S	Sources And Processing	5
		3.1.1	Coastline	5
		3.1.2	Bathymetry	6
		3.1.3	Topography	7
	3.2	Establ	lishing Common Datums	8
		3.2.1	Vertical Datum Transformations	8
		3.2.2	Horizontal Datum Transformations	8
	3.3	Verify	ring consistency between datasets	8
4.			lopment	10
••	4.1		thing of bathymetric data	10
	4.2		ing the MHW DEM	10
	4.3		by Assessment of the structured DEM	12
	1.5	4.3.1	Horizontal accuracy	12
		4.3.2	Vertical accuracy	12
		4.3.3	Slope maps and 3D perspectives	12
5	Cum			15
			nd Conclusions	
			gements	
			ssing Software	
Α.	Sour	се вап	nymetry Data	16
T	ist o	f Fig	nirac	
	ist U	ı ı ıg	uics	
	Figu	re 1.	Shaded relief image of the Sand Point DEM	1
	Figu	re 2.	Overview map illustrating the extents of the Sand Point DEM	3
	Figu	re 3.	Data sources in the Sand Point region.	4
	Figu	re 4.	Tide station locations in the Sand Point region; Sand Point project area shown in red	9
	Figu	re 5.	Data density of Sand Point	11
	Figu		Slope map of the Sand Point DEM	13
	Figu	re 7.	Perspective view from the southwest of the Sand Point DEM	
т :		e Tal	alog	
L	เรเ บ	f Tal	oles	
	Table	e 1.	Specifications for the Sand Point DEM	2
	Table		Shoreline datasets used in compiling the Sand Point DEM	5
	Table		Bathymetric datasets used in compiling the Sand Point DEM	6
	Table		Topographic dataset used in compiling the Sand Point DEM	7
	Table		Relationship between MHW and other vertical datums in the Sand Point region.	8
	Table		Data hierarchy used to assign gridding weight in MB-System	
		e o. e A-1.		11 16
			NOS Hydrographic datasets used in building the Sand Point DEMs	
	raul	C A-2.	TYOO THEIL RESUMMENT TYCHOLISMING CALASERS USED IN DUNCHING THE DAILD FORM DEMIS	41

# Digital Elevation Model of Sand Point, Alaska: Procedures, Data Sources and Analysis

#### 1. Introduction

In March of 2012, the National Geophysical Data Center (NGDC), an office of the National Oceanic and Atmospheric Administration (NOAA), developed a bathymetric–topographic digital elevation model (DEM) of Sand Point, AK (Figure 1). A 1/3 arc-second DEM referenced to mean high water (MHW) was carefully developed and evaluated. The 1/3 arc-second MHW DEM will be used as input for the Method of Splitting Tsunami (MOST) model developed by the Pacific Marine Environmental Laboratory (PMEL) NOAA Center for Tsunami Research (http://nctr.pmel.noaa.gov/) to simulate tsunami generation, propagation and inundation. The DEM was generated from diverse digital datasets in the region (grid boundary and sources shown in Figures 2 and 3). The DEM will be used for tsunami inundation modeling, as part of the tsunami forecast system Short-term Inundation Forecasting for Tsunamis (SIFT) currently being developed by PMEL for the NOAA Tsunami Warning Centers. This report provides a summary of the data sources and methodology used in developing the Sand Point DEM.

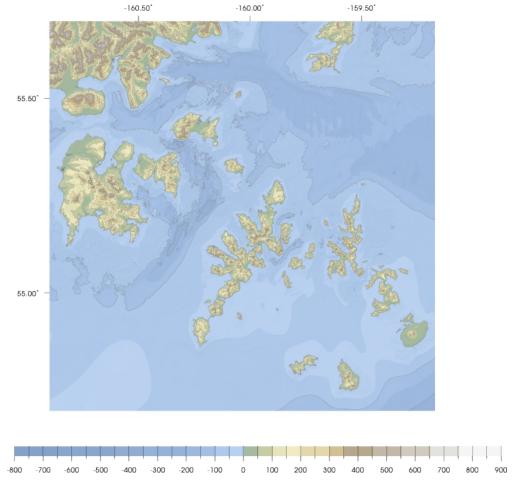


Figure 1. Shaded relief image of the Sand Point DEM.

<sup>&</sup>lt;sup>1</sup>The Sand Point, AK DEM is built upon a grid of cells that are square in geographic coordinates (latitude and longitude), however, the cells are not square when converted to projected coordinate systems, such as UTM zones (in meters). At the latitude of Sand Point, AK, 1/3 arc-second of latitude is equivalent to 10.29556 meters; 1/3 arc-second of longitude equals 7.95 meters

# 2. STUDY AREA

The Sand Point DEM covers the region surrounding Sand Point, Alaska (Figure 2) and includes the communities of Sand Point and Unga Alaska, as well as numerous surrounding islands. The Sand Point region is located along the Alaska Peninsula in the Borough of Aleutians East.

Table 1. Specifications for the Sand Point DEM

Grid Area	Sand Point, AK		
Coverage Area	-60.9°, 55.7°, -159.17°, 54.7°		
Coordinate System	Geographic decimal degrees		
Horizontal Datum	North American Datum of 1983 (NAD 83)		
Vertical Datum	MHW		
Vertical Units	Meters		
Grid Spacing	1/3 arc-second		
Grid Format	ESRI Arc ASCII grid		

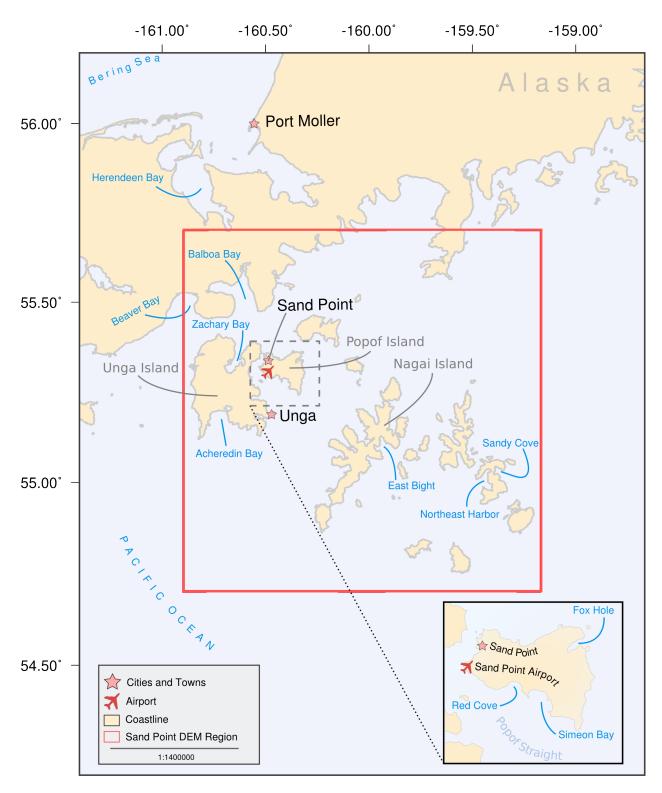


Figure 2. Overview map illustrating the extents of the Sand Point DEM

## 3. SOURCE ELEVATION DATA

The best available digital data were obtained by NGDC from two U.S. federal agencies: NOAA's NGDC and the United States Geological Survey (USGS). Data were gathered in an area slightly larger ( $\sim$ 5%) than the DEM extents. This data 'buffer' ensures that gridding occurs across rather than along the DEM boundaries to prevent edge effects. Data processing and evaluation, as well as DEM assembly and assessment are described in the following subsections.

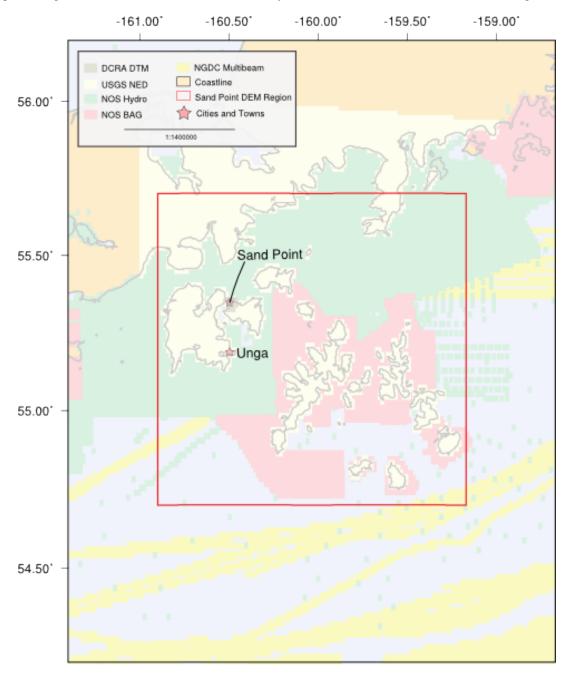


Figure 3. Data sources in the Sand Point region.

### 3.1 Data Sources And Processing

Coastline, bathymetric, and topographic digital datasets (Tables 2, 3, and 4; Figure 3) were obtained by NGDC and shifted to common horizontal and vertical datums: NAD 83 geographic<sup>2</sup> and MHW, respectively. The datasets were assessed to determine data quality and were manually edited where needed. Vertical datum transformations to MHW were accomplished using a constant offset based on the tidal relationships shown in Table 5.

#### 3.1.1 Coastline

Coastline datasets of the Sand Point region were obtained from a variety of sources. The main dataset used in developing a combined, detailed coastline was the NOAA Office of Coast Survey (OCS) digitized vector coastline (Table 2). This dataset provided a medium resolution coastline of the Sand Point region.

The OCS coastline was edited by NGDC using ESRI World Imagery to better represent the coastline immediately sourrounding bays and inlets and to ensure the resolution of the breakwaters in the region, which were not adequately represented in other data sources.

Table 2. Shoreline datasets used in compiling the Sand Point DEM

Source	Year	Data Type	Spatial Resolution	Original Horizontal Datum/Coordinate System	Original Vertical Coordinate System	URL
OCS	2011	Digitized vector Coastline	Not defined	World Geodetic System (WGS) 84 geographic	MHW	N/A
NGDC	2011	Digitized vector Coastline	Not defined	World Geodetic System (WGS) 84 geographic	MHW	N/A

<sup>&</sup>lt;sup>2</sup>The horizontal difference between the North American Datum of 1983 (NAD 83) and World Geodetic System of 1984 (WGS 84) geographic horizontal datums is approximately one meter across the contiguous U.S., which is significantly less than the cell size of the DEM. Many GIS applications treat the two datums as identical, so do not actually transform data between them, and the error introduced by not converting between the datums is insignificant for our purposes. NAD 83 is restricted to North America, while WGS 84 is a global datum. As tsunamis may originate most anywhere around the world, tsunami modelers require a global datum, such as WGS 84 geographic, for their DEMs so that they can model the waves passage across ocean basins. This DEM is identified as having a WGS 84 geographic horizontal datum even though the underlying elevation data were typically transformed to NAD 83 geographic. At the scale of the DEM, WGS 84 and NAD 83 geographic are identical and may be used interchangeably.

### 3.1.2 Bathymetry

Bathymetric datasets available in the Sand Point region included 22 NGDC multibeam sonar surveys, 184 National Ocean Survey (NOS) high-resolution surveys in Bathymetric Attributed Grid (BAG) format, and 55 NOAA NOS Hydro surveys (Table 3; Figure 3). NGDC evaluated but did not use the OCS Electronic Nautical Charts (ENCs) that were available from OCS due to conflicts with the other bathymetric surveys.

Table 3. Bathymetric datasets used in compiling the Sand Point DEM

Source	Year	Data Type	Spatial Resolution	Original Horizontal Datum/Coordinate System	Original Vertical Coordinate System	URL
NGDC	2011	Multibeam soundings	N/A	NAD 83 geographic	Assumed mean sea level (MSL)	http://www.ngdc. noaa.gov/mgg/ bathymetry/ multibeam.html
NOS BAG	2004 - 2009	Soundings	N/A	NAD 83 geographic	mean lower low water (MLLW)	N/A
NOS Hydro	1910 - 2004	Soundings	N/A	NAD 83 geographic	MLLW	http://www.ngdc. noaa.gov/mgg/ bathymetry/hydro. html

#### 1) NGDC Multibeam

Twenty-two multibeam swath sonar surveys were available from the NGDC multibeam database for use in the development of the Sand Point DEM (Figure 3). This database is comprised of the original swath sonar files of surveys conducted mostly by the U.S. academic fleet. All surveys have a horizontal datum of WGS 84 geographic and an undefined vertical datum, assumed to be equivalent to NAVD 88. The data were gridded to 1 arc-second resolution using MB-System and xyz data were transformed to MHW using a constant offset (Section 3.2).

#### 2) NOS/BAG Hydrographic Surveys

A total of 184 NOS high-resolution hydrographic surveys, in BAG format, were conducted between 2008 and 2009 and were available for use in the development of the Sand Point DEM (Figure 3). The data were vertically referenced to MLLW and horizontally referenced to NAD 83 geographic and were transformed to MHW using a constant offset (Section 3.2).

#### 3) NOS Hydrographic Surveys

A total of 55 NOS hydrographic surveys were available for use in the development of the Sand Point DEM (Figure 3). The data were vertically referenced to MLLW and horizontally referenced to NAD 83 geographic and were transformed to MHW using a constant offset (Section 3.2).

## 3.1.3 Topography

The topographic datasets used to build the Sand Point DEM were the US Geological Society (USGS) National Elevation Dataset (NED) 2 arc-second DEM and the NGDC 2006 3 arc-second DEM of Sand Point, AK (Table 4; Figure 3).

Table 4. Topographic dataset used in compiling the Sand Point DEM

Source	Year	Data Type	Spatial Resolution	Original Horizontal Datum/Coordinate System	Original Vertical Coordinate System	URL
USGS	2011	Bare-earth DEM	5 - 10 meters	WGS 84 geographic	NAVD 88	N/A
NGDC	2006	Bare-earth DEM	1 - 10 meters	WGS 84 geographic	MHW	http://www.ngdc. noaa.gov/dem/ squareCellGrid/ download/395

#### 1) USGS NED 2 arc-second DEM

The USGS NED provides complete 2 arc-second coverage of Western Alaska. Data are in NAD 83 geographic coordinate and assumed MSL vertical datum (meters), and are available for download as raster DEMs. The bare-earth elevations have a vertical accuracy of +/- 7 to 15 meters depending on source data resolution. See the USGS Seamless web site for specific source information (http://seamless.usgs.gov). The dataset was derived from USGS quadrange maps and aerial photographs based on topographic surveys; it has been revised using data collected in 1999. The NED DEMs were transformed to NAD 83 and MHW using *proj4* and a constant offset. respectively (Section 3.2; Table 5). The gridded data were evaluated and positive elevations over open water were removed by clipping the data to the coastline using *GDAL* and *Python*. The resulting data were converted to xyz data using *GDAL*.

#### 2) NGDC 3 Arc-second DEM

In 2006 NGDC developed a 3 arc-second DEM of Sand Point, Alaska (http://www.ngdc.noaa.gov/dem/squareCellGrid/download/395). See the associated development report for specific source information. The NGDC DEM data was extracted to xyz format and clipped to the Sand Point region coastline to be used as a source dataset for topographic regions in the Sand Point DEM.

# 3.2 Establishing Common Datums

## 3.2.1 Vertical Datum Transformations

Datasets used in the compilation and evaluation of the Sand Point DEM were originally referenced to MLLW, MSL or NAVD 88. All datasets were transformed to MHW using constant offsets obtained from averaging the differences between datums at various tidal gauges around Oahu (Table 5; Fig. 4).

- **Bathymetric Data:** All hydrographic surveys were transformed from MLLW or NAVD 88 to MHW using a constant offset based on the tidal relationships shown in Table 5.
- **Topographic Data:** All topographic datasets used in the compilation of the Sand Point DEM originated in NAD 88 vertical datum and were transformed to MHW using a constant offset based on the tidal relationships shown in Table 5.

Table 5. Relationship between MHW and other vertical datums in the Sand Point region

Station Name	Difference to MHW (meters)		
Sand Point	MSL	.807	
Sand Tonn	MLLW	1.988	
King Cove	MSL	0.750	
Timing Cort	MLLW	1.875	
Port Moller	MSL	1.145	
	MLLW	2.919	
Average	MSL	-0.231	
Avelage	MLLW	-0.504	

#### 3.2.2 Horizontal Datum Transformations

Datasets used to build the Sand Point DEM were downloaded or received referenced to WGS 84 geographic or NAD 83 geographic horizontal datums. The relationship transformational equations between these horizontal datums are well established. Data were transformed to a horizontal datum of NAD 83 geographic using *Proj4*.<sup>3</sup>

#### 3.3 Verifying consistency between datasets

After horizontal and vertical transformations were applied, the ascii xyz files were reviewed for consistency between datasets. Problems and errors were identified and resolved before proceeding with subsequent gridding steps.

 $<sup>^3</sup>Proj4$  is a free standard Unix filter function which converts geographic longitude and latitude coordinates into cartesian coordinates,  $(\lambda, \phi) \rightarrow (x, y)$ , by means of a wide variety of cartographic projection functions. http://trac.osgeo.org/proj/

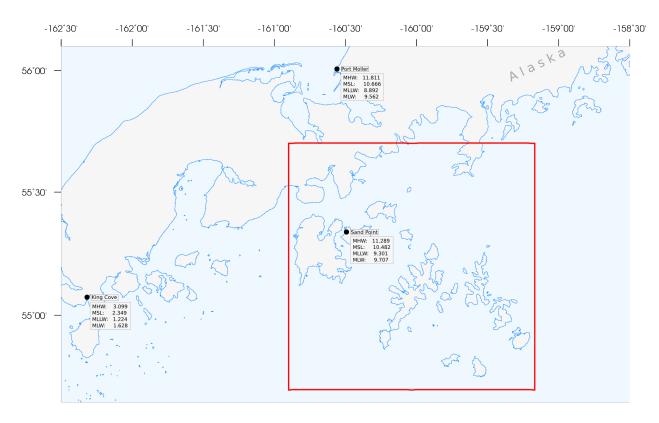


Figure 4. Tide station locations in the Sand Point region; Sand Point project area shown in red.

#### 4. **DEM DEVELOPMENT**

## 4.1 Smoothing of bathymetric data

The NGDC multibeam hydrographic survey data are generally sparse relative to the resolution of the 1/3 arcsecond Sand Point DEM. This is especially true for deep water surveys in the Pacific and shallow water surveys in bays where data have point spacing up to 350 meters apart. In order to reduce artifacts created in the DEM by the low-resolution bathymetric datasets, and to provide effective interpolation in the deep water and into the coastal zone, a 1 arc-second pre-surface bathymetric grid was generated using Generic Mapping Tools  $(GMT)^4$ . The coastline elevation value was set at 0 meters to ensure a bathymetric surface below zero in areas where data are sparse or non-existent.

The point data were median-averaged using the GMT command "blockmedian" to create a 1 arc-second grid 0.05 degrees ( $\sim$ 5%) larger than the Sand Point DEM gridding region. The GMT command "surface" was then used to apply a tight spline tension to interpolate elevations for cells without data values. The GMT grid created by 'surface' was converted to an ESRI Arc ASCII grid file, and clipped to the final coastline (to eliminate data interpolation onto land areas) using GDAL and Python. The resulting surface was exported as an xyz file for use in the final gridding process (Table 6).

# **4.2** Building the MHW DEM

MB-System<sup>5</sup> was used to create the 1/3 arc-second Sand Point MHW DEM. The MB-System command "mb-grid" was used to apply a tight spline tension to the *xyz* data, and interpolate values for cells without data. The data hierarchy used in the "mbgrid" gridding algorithm, as relative gridding weights, is listed in Table 6. The resulting binary grid was converted to an Arc ASCII grid using the *MB-System* tool "mbm-grd2arc" to create the final 1/3 arc-second Sand Point MHW DEM. Figure 5 illustrates cells in the DEM that have interpolated values versus data contributing to the cell value.

 $<sup>^4</sup>GMT$  is an open source collection of  $\sim$ 60 tools for manipulating geographic and Cartesian data sets (including filtering, trend fitting, gridding, projecting, etc.) and producing Encapsulated PostScript File (EPS) illustrations ranging from simple x-y plots via contour maps to artificially illuminated surfaces and 3-D perspective views. GMT supports  $\sim$ 30 map projections and transformations and comes with support data such as GSHHS coastlines, rivers, and political boundaries. GMT is developed and maintained by Paul Wessel and Walter H. F. Smith with help from a global set of volunteers, and is supported by the National Science Foundation. It is released under the GNU General Public License. URL: http://gmt.soest.hawaii.edu/ [Extracted from GMT web site.]

<sup>&</sup>lt;sup>5</sup>MB-System is an open source software package for the processing and display of bathymetry and backscatter imagery data derived from multibeam, interferometry, and sidescan sonars. The source code for MB-System is freely available (for free) by anonymous ftp (point and access through these web pages). A complete description is provided in web pages accessed through the web site. MB-System was originally developed at the Lamont-Doherty Earth Observatory of Columbia University (L-DEO) and is now a collaborative effort between the Monterey Bay Aquarium Research Institute (MBARI) and L-DEO. The National Science Foundation has provided the primary support for MB-System development since 1993. The Packard Foundation has provided significant support through MBARI since 1998. Additional support has derived from SeaBeam Instruments (1994–1997), NOAA (2002–2004), and others. URL: http://www.ldeo.columbia.edu/res/pi/MB-System/ [Extracted from MB-System web site.]

Table 6. Data hierarchy used to assign gridding weight in MB-System

Dataset	Relative Gridding Weight
NOS BAG	50
USGS NED	20
NOS Hydro	10
Pre-surfaced bathymetric grid	1

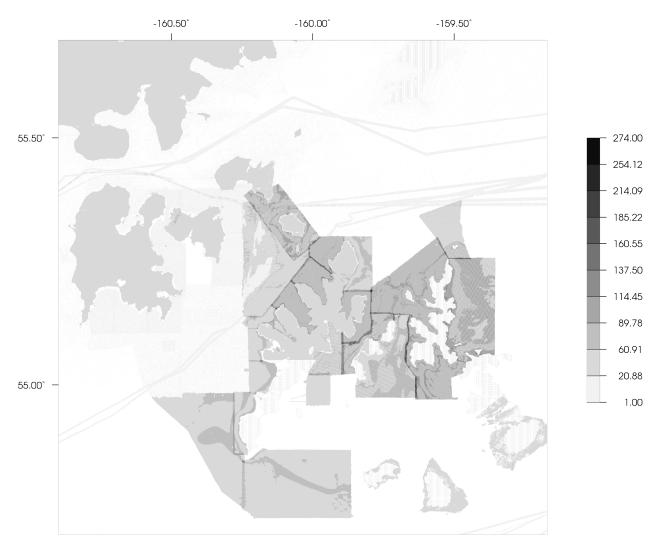


Figure 5. Data density of the Sand Point gridding region.

## 4.3 Quality Assessment of the structured DEM

## 4.3.1 Horizontal accuracy

The horizontal accuracy of topographic and bathymetric features in the Sand Point DEM is dependent upon the datasets used to determine corresponding DEM cell values and the cell size of the DEM, making the highest accuracy possible 1/3 arc-seconds (about 10 meters). Bathymetric features are resolved only to within a few tens of meters in deep-water areas. Shallow, near-coastal regions, rivers, and harbor surveys have an accuracy approaching that of sub aerial topographic features. Positional accuracy is limited by: the sparseness of deep-water soundings; and by the morphologic change that occurs in this dynamic region.

# 4.3.2 Vertical accuracy

Vertical accuracy of the Sand Point DEM is also highly dependent upon the source datasets contributing to DEM cell values. Topographic NED data have an estimated accuracy of 7 - 20 meters. Bathymetric areas have an estimated accuracy of between 0.1 meters and 5% of water depth.

# 4.3.3 Slope maps and 3D perspectives

*GMT* was used to generate a slope grid from the Sand Point DEM to allow for visual inspection and identification of artificial slopes along boundaries between datasets (Figure 6). The DEM was transformed to projected coordinates (horizontal units in meters) using *GMT* for derivation of the slope grid; equivalent horizontal and vertical units are required for effective slope analysis. Analysis of preliminary grids revealed suspect data points, which were corrected before recompiling the DEM. Figure 7 shows a perspective view image of the 1/3 arc-second Sand Point DEM in its final version.

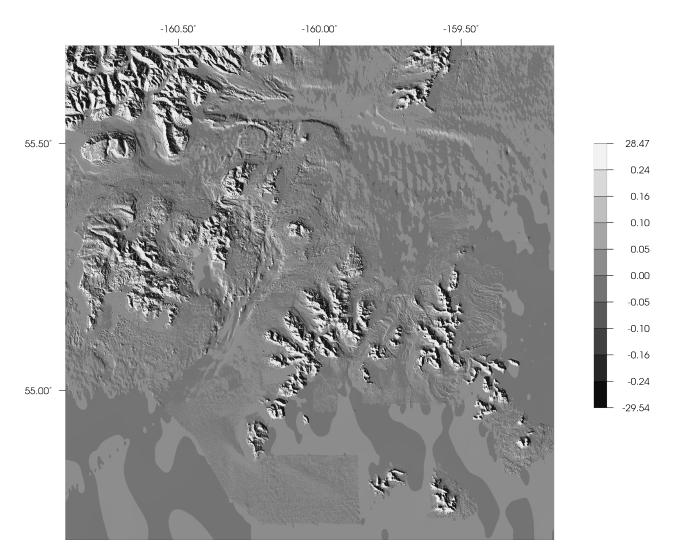
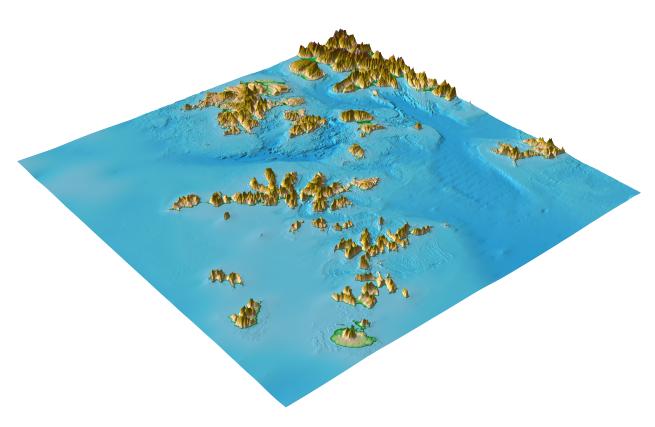


Figure 6. Slope map of the Sand Point DEM



**Figure 7.** Perspective view from the southwest of the Sand Point DEM.

#### 5. SUMMARY AND CONCLUSIONS

A bathymetric-topographic structured digital elevation model of the Sand Point, AK region, with cell spacing of 1/3 arc-second, and a vertical datum of MHW was developed by NGDC for PMEL for use in tsunami generation, propagation and inundation simulations.

Recommendations to improve the Sand Point DEM, based on NGDC's research and analysis, are listed below:

- Conduct publically available lidar surveys of all topographic regions.
- Conduct publically available high-resolution surveys of all harbors and bays.

#### 6. ACKNOWLEDGEMENTS

The creation of the Sand Point DEM was funded by NOAA PMEL. The authors thank Marie Eble, Lindsey Wright and Vasily Titov (PMEL).

#### 7. REFERENCES

Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A, 2003. Federal Emergency Management Agency, Flood Hazard Mapping Program.

Taylor et al., Digital Elevation Models of Sand Point, AK: Procedures, Data Sources and Analysis. National Geophysical Data Center.

#### 8. DATA PROCESSING SOFTWARE

ArcGIS 10, developed and liscensed by ESRI, Redlands, California, http://www.esri.com

ESRI World Imagery - ESRI ArcGIS Resource Centers, http://www.esri.com

- **GEODAS v. 5** Geophysical Data System, free software developed and maintained by Dan Metzger, NOAA National Geophysical Data Center, http://www.ngdc.noaa.gov/mgg/geodas
- **GMT v. 4.1.4** Generic Mapping Tools, free software developed and maintained by Paul Wessel and Walter Smith, funded by the National Science Foundation, <a href="http://gmt.soest.hawaii.edu">http://gmt.soest.hawaii.edu</a>
- **MB-System v. 5.1.0,** free software developed and maintained by David W. Caress and Dale N. Chayes, funded by the National Science Foundation, <a href="http://www.ldeo.columbia.edu/res/pi/MB-System">http://www.ldeo.columbia.edu/res/pi/MB-System</a>
- **Quick Terrain Modeler v. 6.0.1,** lidar processing software developed by John Hopkins University's Applied Physics Laboratory (APL) and maintained and licensed by Applied Imagery, <a href="http://www.appliedimagery.com">http://www.appliedimagery.com</a>
- **GDAL v. 1.8.0** Geographic Data Abstraction Library is a translator library maintained by Frank Warmerdam, http://gdal.org
- **Proj4 v. 4.7.0** free software developed by Gerald Evenden and maintained by Frank Warmerdam, <a href="http://trac.osgeo.org/proj/">http://trac.osgeo.org/proj/</a>

# A. SOURCE BATHYMETRY DATA

Table A-1. NOS Hydrographic datasets used in building the Sand Point DEMs

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H03194	1910	Undetermined	Mean Lower Low Water	Undetermined horizontal datum
H03574	1913	1:20,000	Mean Lower Low Water	Undetermined horizontal datum
H03578	1913	1:10,000	Mean Lower Low Water	North American Datum 1983
H03654	1913	1:100,000	Mean Lower Low Water	North American Datum 1983
H03706	1914	1:20,000	Mean Lower Low Water	North American Datum 1983
H03713	1914	1:20,000	Mean Lower Low Water	North American Datum 1983
H03714	1914	1:20,000	Mean Lower Low Water	North American Datum 1983
H03715	1914	1:10,000	Mean Lower Low Water	North American Datum 1983
H03716	1914	1:20,000	Mean Lower Low Water	North American Datum 1983
H03722	1914	1:100,000	Mean Lower Low Water	North American Datum 1983
Н03796	1915	1:100,000	Mean Lower Low Water	North American Datum 1983

Table A-1 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H03806	1915	1:20,000	Mean Lower Low Water	North American Datum 1983
H03807	1915	1:20,000	Mean Lower Low Water	Undetermined horizontal datum
H03808	1915	1:5,000	Mean Lower Low Water	Undetermined horizontal datum
H03809	1915	1:20,000	Mean Lower Low Water	Undetermined horizontal datum
H04378	1924	1:20,000	Mean Lower Low Water	North American Datum 1983
H04381	1924	1:20,000	Mean Lower Low Water	Undetermined horizontal datum
H04393	1924	1:20,000	Mean Lower Low Water	North American Datum 1983
H06594	1941	20,000	Mean Lower Low Water	North American Datum 1983
H06741	1941	10,000	Mean Lower Low Water	North American Datum 1983
H06771	1942	20,000	Mean Lower Low Water	North American Datum 1983
H06774	1942	60,000	Mean Lower Low Water	North American Datum 1983

Table A-1 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H06880	1943	120,000	Mean Lower Low Water	North American Datum 1983
H06927	1943	40,000	Mean Lower Low Water	North American Datum 1983
H07169	1946	80,000	Mean Lower Low Water	North American Datum 1983
H07839	1950	1,000	Mean Lower Low Water	North American Datum 1983
H07872	1950	1,000	Mean Lower Low Water	North American Datum 1983
H07923	1953	20,000	Mean Lower Low Water	North American Datum 1983
H07926	1952	20,000	Mean Lower Low Water	North American Datum 1983
H07927	1951	40,000	Mean Lower Low Water	North American Datum 1983
Н07996	1953	20,000	Mean Lower Low Water	North American Datum 1983
H07997	1953	20,000	Mean Lower Low Water	North American Datum 1983
H07998	1953	20,000	Mean Lower Low Water	North American Datum 1983

Table A-1 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
Н07999	1952	40,000	Mean Lower Low Water	North American Datum 1983
H08000	1952	40,000	Mean Lower Low Water	North American Datum 1983
H08045	1953	20,000	Mean Lower Low Water	North American Datum 1983
H08046	1953	20,000	Mean Lower Low Water	North American Datum 1983
H08047	1953	20,000	Mean Lower Low Water	North American Datum 1983
H08048	1953	20,000	Mean Lower Low Water	North American Datum 1983
H08049	1953	20,000	Mean Lower Low Water	North American Datum 1983
H08089	1955	25,000	Mean Lower Low Water	North American Datum 1983
H08156	1954	20,000	Mean Lower Low Water	North American Datum 1983
H08157	1954	25,000	Mean Lower Low Water	North American Datum 1983
H08158	1954	25,000	Mean Lower Low Water	North American Datum 1983

Table A-1 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H08159	1954	25,000	Mean Lower Low Water	North American Datum 1983
H08228	1955	1:20,000	Mean Lower Low Water	North American Datum 1983
H11278	2004	10,000	MLLW	North American Datum 1983
H11279	2004	10,000	MLLW	North American Datum 1983
H11280	2004	10,000	MLLW	North American Datum 1983
H11281	2004	10,000	MLLW	North American Datum 1983
H11326	2004	20,000	MLLW	North American Datum 1983
H11327	2004	10,000	MLLW	North American Datum 1983
H11328	2004	10,000	MLLW	North American Datum 1983
H11329	2004	20,000	MLLW	North American Datum 1983
H11332	2004	Undetermined	MLLW	North American Datum 1983

Table A-2. NOS High Resolution Hydrographic datasets used in building the Sand Point DEMs

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11261	2004	Undetermined	MLLW	North American Datum 1983
H11262	2004	Undetermined	MLLW	North American Datum 1983
H11263	2004	Undetermined	MLLW	North American Datum 1983
H11264	2004	Undetermined	MLLW	North American Datum 1983
H11265	2004	Undetermined	MLLW	North American Datum 1983
H11266	2004	Undetermined	MLLW	North American Datum 1983
H11330	2004	Undetermined	MLLW	North American Datum 1983
H11430	2005	Undetermined	MLLW	North American Datum 1983
H11431	2005	Undetermined	MHW	North American Datum 1983
H11432	2005	Undetermined	MLLW	North American Datum 1983
H11432	2005	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11433	2005	Undetermined	MLLW	North American Datum 1983
H11434	2005	Undetermined	MLLW	North American Datum 1983
H11435	2005	Undetermined	MLLW	North American Datum 1983
H11472	2005	Undetermined	MLLW	North American Datum 1983
H11472	2005	Undetermined	MLLW	North American Datum 1983
H11473	2005	Undetermined	MLLW	North American Datum 1983
H11473	2005	Undetermined	MLLW	North American Datum 1983
H11473	2005	Undetermined	MLLW	North American Datum 1983
H11474	2005	Undetermined	MLLW	North American Datum 1983
H11474	2005	Undetermined	MLLW	North American Datum 1983
H11476	2005	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11476	2005	Undetermined	MLLW	North American Datum 1983
H11476	2005	Undetermined	MLLW	North American Datum 1983
H11476	2005	Undetermined	MLLW	North American Datum 1983
H11476	2005	Undetermined	MLLW	North American Datum 1983
H11476	2005	Undetermined	MLLW	North American Datum 1983
H11476	2005	Undetermined	MLLW	North American Datum 1983
H11476	2005	Undetermined	MLLW	North American Datum 1983
H11476	2005	Undetermined	MLLW	North American Datum 1983
H11476	2005	Undetermined	MLLW	North American Datum 1983
H11477	2005	Undetermined	MLLW	North American Datum 1983
H11477	2005	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11477	2005	Undetermined	MLLW	North American Datum 1983
H11477	2005	Undetermined	MLLW	North American Datum 1983
H11478	2005	Undetermined	MLLW	North American Datum 1983
H11478	2005	Undetermined	MLLW	North American Datum 1983
H11478	2005	Undetermined	MLLW	North American Datum 1983
H11478	2005	Undetermined	MLLW	North American Datum 1983
H11478	2005	Undetermined	MLLW	North American Datum 1983
H11478	2005	Undetermined	MLLW	North American Datum 1983
H11478	2005	Undetermined	MLLW	North American Datum 1983
H11478	2005	Undetermined	MLLW	North American Datum 1983
H11478	2005	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11478	2005	Undetermined	MLLW	North American Datum 1983
H11478	2005	Undetermined	MLLW	North American Datum 1983
H11478	2005	Undetermined	MLLW	North American Datum 1983
H11478	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11479	2005	Undetermined	MLLW	North American Datum 1983
H11482	2005	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11482	2005	Undetermined	MLLW	North American Datum 1983
H11489	2005	Undetermined	MLLW	North American Datum 1983
H11489	2005	Undetermined	MLLW	North American Datum 1983
H11489	2005	Undetermined	MLLW	North American Datum 1983
H11517	2006	Undetermined	MLLW	North American Datum 1983
H11517	2006	Undetermined	MLLW	North American Datum 1983
H11517	2006	Undetermined	MLLW	North American Datum 1983
H11517	2006	Undetermined	MLLW	North American Datum 1983
H11518	2006	Undetermined	MLLW	North American Datum 1983
H11518	2006	Undetermined	MLLW	North American Datum 1983
H11518	2006	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11518	2006	Undetermined	MLLW	North American Datum 1983
H11519	2006	Undetermined	MLLW	North American Datum 1983
H11519	2006	Undetermined	MLLW	North American Datum 1983
H11519	2006	Undetermined	MLLW	North American Datum 1983
H11519	2006	Undetermined	MLLW	North American Datum 1983
H11520	2006	Undetermined	MLLW	North American Datum 1983
H11520	2006	Undetermined	MLLW	North American Datum 1983
H11521	2006	Undetermined	MLLW	North American Datum 1983
H11521	2006	Undetermined	MLLW	North American Datum 1983
H11521	2006	Undetermined	MLLW	North American Datum 1983
H11580	2006	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11580	2006	Undetermined	MLLW	North American Datum 1983
H11580	2006	Undetermined	MLLW	North American Datum 1983
H11580	2006	Undetermined	MLLW	North American Datum 1983
H11580	2006	Undetermined	MLLW	North American Datum 1983
H11582	2006	Undetermined	MLLW	North American Datum 1983
H11582	2006	Undetermined	MLLW	North American Datum 1983
H11582	2006	Undetermined	MLLW	North American Datum 1983
H11582	2006	Undetermined	MLLW	North American Datum 1983
H11587	2006	Undetermined	MLLW	North American Datum 1983
H11587	2006	Undetermined	MLLW	North American Datum 1983
H11587	2006	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11593	2006	Undetermined	MLLW	North American Datum 1983
H11593	2006	Undetermined	MLLW	North American Datum 1983
H11593	2006	Undetermined	MLLW	North American Datum 1983
H11593	2006	Undetermined	MLLW	North American Datum 1983
H11593	2006	Undetermined	MLLW	North American Datum 1983
H11594	2006	Undetermined	MLLW	North American Datum 1983
H11594	2006	Undetermined	MLLW	North American Datum 1983
H11594	2006	Undetermined	MLLW	North American Datum 1983
H11594	2006	Undetermined	MLLW	North American Datum 1983
H11594	2006	Undetermined	MLLW	North American Datum 1983
H11595	2006	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11595	2006	Undetermined	MLLW	North American Datum 1983
H11595	2006	Undetermined	MLLW	North American Datum 1983
H11595	2006	Undetermined	MLLW	North American Datum 1983
H11595	2006	Undetermined	MLLW	North American Datum 1983
H11596	2006	Undetermined	MLLW	North American Datum 1983
H11596	2006	Undetermined	MLLW	North American Datum 1983
H11596	2006	Undetermined	MLLW	North American Datum 1983
H11596	2006	Undetermined	MLLW	North American Datum 1983
H11597	2006	Undetermined	MLLW	North American Datum 1983
H11597	2006	Undetermined	MLLW	North American Datum 1983
H11597	2006	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11597	2006	Undetermined	MLLW	North American Datum 1983
H11606	2006	Undetermined	MLLW	North American Datum 1983
H11606	2006	Undetermined	MLLW	North American Datum 1983
H11606	2006	Undetermined	MLLW	North American Datum 1983
H11606	2006	Undetermined	MLLW	North American Datum 1983
H11606	2006	Undetermined	MLLW	North American Datum 1983
H11607	2006	Undetermined	MLLW	North American Datum 1983
H11607	2006	Undetermined	MLLW	North American Datum 1983
H11607	2006	Undetermined	MLLW	North American Datum 1983
H11607	2006	Undetermined	MLLW	North American Datum 1983
H11607	2006	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11676	2007	Undetermined	MLLW	North American Datum 1983
H11676	2007	Undetermined	MLLW	North American Datum 1983
H11676	2007	Undetermined	MLLW	North American Datum 1983
H11676	2007	Undetermined	MLLW	North American Datum 1983
H11682	2007	Undetermined	MLLW	North American Datum 1983
H11682	2007	Undetermined	MLLW	North American Datum 1983
H11682	2007	Undetermined	MLLW	North American Datum 1983
H11682	2007	Undetermined	MLLW	North American Datum 1983
H11848	2008	Undetermined	MLLW	North American Datum 1983
H11848	2008	Undetermined	MLLW	North American Datum 1983
H11848	2008	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H11848	2008	Undetermined	MLLW	North American Datum 1983
H11848	2008	Undetermined	MLLW	North American Datum 1983
H11923	2008	Undetermined	MLLW	North American Datum 1983
H12070	2009	Undetermined	MLLW	North American Datum 1983
H12070	2009	Undetermined	MLLW	North American Datum 1983
H12070	2009	Undetermined	MLLW	North American Datum 1983
H12070	2009	Undetermined	MLLW	North American Datum 1983
H12070	2009	Undetermined	MLLW	North American Datum 1983
H12072	2009	Undetermined	MLLW	North American Datum 1983
H12072	2009	Undetermined	MLLW	North American Datum 1983
H12072	2009	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H12072	2009	Undetermined	MLLW	North American Datum 1983
H12072	2009	Undetermined	MLLW	North American Datum 1983
H12078	2009	Undetermined	MLLW	North American Datum 1983
H12078	2009	Undetermined	MLLW	North American Datum 1983
H12078	2009	Undetermined	MLLW	North American Datum 1983
H12078	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983
H12081	2009	Undetermined	MLLW	North American Datum 1983

Table A-2 – Continued

Survey ID	Year	Scale/Vertical Accuracy	Original Vertical Datum	Provided Horizontal Datum
H12101	Unkn	Undetermined	MLLW	North American Datum 1983
H12102	Unkn	Undetermined	MLLW	North American Datum 1983
H12103	Unkn	Undetermined	MLLW	North American Datum 1983
H12104	Unkn	Undetermined	MLLW	North American Datum 1983
H12119	2009	Undetermined	MLLW	North American Datum 1983
H12119	2009	Undetermined	MLLW	North American Datum 1983
H12119	2009	Undetermined	MLLW	North American Datum 1983
H12119	2009	Undetermined	MLLW	North American Datum 1983